

Analogue Input Calibration of the ATLAS Level-1 Calorimeter Trigger

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On behalf of the ATLAS TDAQ Collaboration

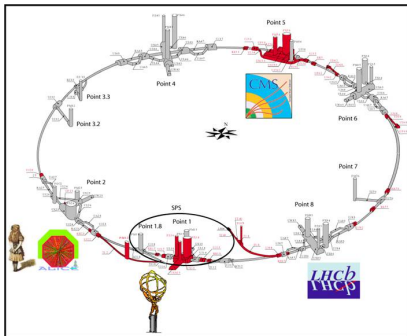
The ATLAS Trigger/DAQ Authorlist, version 3.0
ATL-DAQ-PUB-2009-007
CERN, Geneva, 2009
<http://cdsweb.cern.ch/record/1207077>

Talk Outline

Talk Outline

- ① Introduction to the LHC, ATLAS & L1Calo
- ② Timing calibration:
 - PreProcessor coarse timing
 - PreProcessor fine timing
- ③ Internal calibration:
 - Setting the pedestal
 - Bunch-crossing Identification
- ④ Energy calibration:
 - Electronic calibration using pulser runs
- ⑤ Plans for 1st beam

The LHC



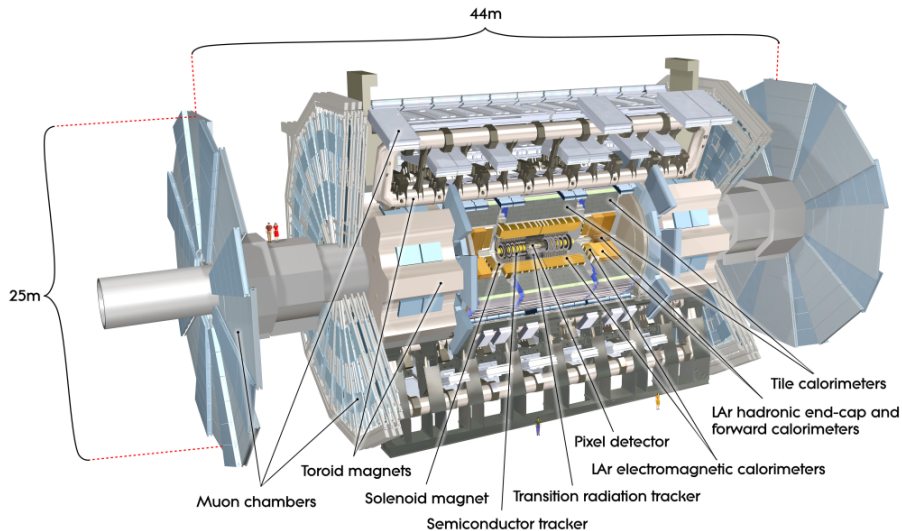
The LHC

- pp collisions at $\sqrt{s}_{\text{max}} = 14 \text{ TeV}$
- Bunch-crossing 25ns
- 10^{11} protons per bunch
- Design luminosity $L_o = 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- $\int \mathcal{L} = 100 \text{ fb}^{-1}$ per year
- Collisions due in 2009

The 4 LHC Detectors

- ATLAS & CMS : pp collisions, Standard Model and beyond
- LHCb : pp collisions, B physics, CP violation
- ALICE : ion-ion, pp collisions, quark-gluon plasma

The ATLAS Detector



The ATLAS Trigger

Level-1

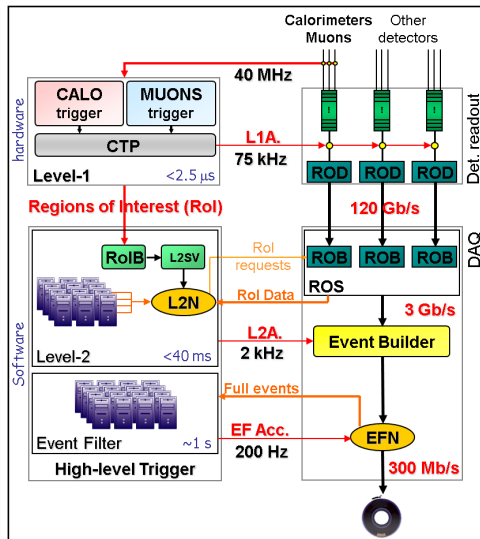
- Hardware (ASICs & FPGAs)
- Calorimeters & Muons
- Latency $< 2.5\mu\text{s}$. L1A 75 kHz

Level-2

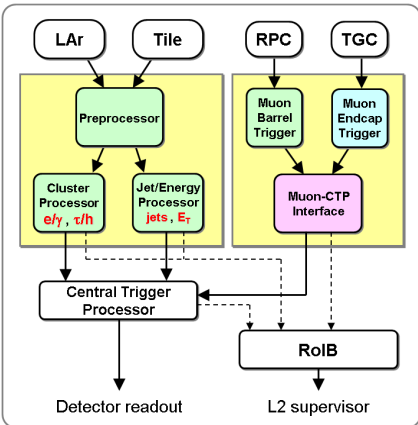
- ~ 500 dual CPUs
- Full granularity
- Input L1 Regions of Interest
 - small, energetic area of η, ϕ
- Latency ~ 40 ms. L2A 2 kHz

Event Filter (Level-3)

- ~ 1600 dual CPUs
- Full event
- Calibration constants
- Offline algorithms
- Latency ~ 1 s. EFA 200 Hz



Level-1 Trigger system (L1)



3 sub-systems

- L1 - Calorimeters (L1Calo)
- L1 - Muons
- Central Trigger Processor (CTP)

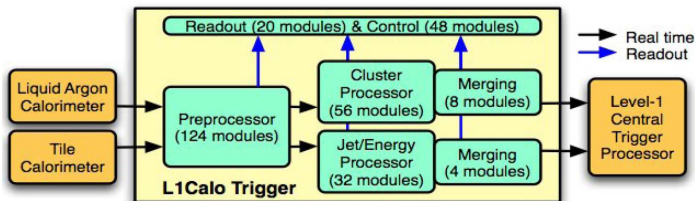
Signature identification

- Multiplicities per E_T threshold
- L1Calo:
 - Isolation criteria
 - e/γ , τ/h , jets
 - Missing E_T , total E_T
- L1 Muons:
 - μ

CTP

- Receive & synchronise trigger info
- Generate L1 trigger decision (L1A)

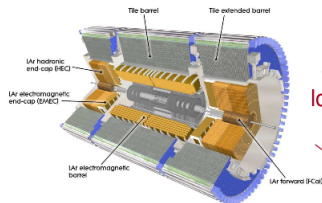
The L1 Calorimeter Trigger (L1Calo)



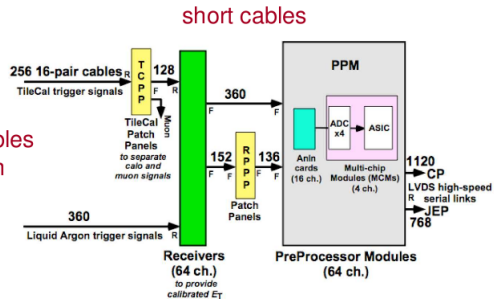
The L1 Calorimeter Trigger (L1Calo)

- Fixed latency ($\sim 2\mu s$), pipe-lined, hardware based system using custom electronics
- Nearly 300 VME modules of 10 different types housed in 17 crates
- Entirely located off the detector in the service cavern USA15
- **PreProcessor PPr:**
Digitisation and bunch-crossing identification
- **Cluster Processor CP:**
Identifies electrons, photons and single hadrons
- **Jet/Energy-sum Processor JEP:**
Jet finding and energy sums

Analogue signal chain



long cables
~70m



Analogue signal from calorimeters to L1Calo

- About 250k calorimeter cells summed to 7168 trigger towers
- Granularity 0.1×0.1 in η, ϕ (central region $|\eta| < 2.5$)
- E_T calibration in receiver system
- Timing calibration, conditioning and digitisation in PPR
- Calibrated E_T transmitted to CP/JEP for object identification

PreProcessors & Energy reconstruction

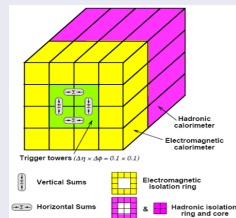
PreProcessors & Energy reconstruction

- Receivers:
 - Input signal conditioning to L1 ($2.5 \text{ V} \rightarrow 250 \text{ GeV}$)
 - Variable gain amplifier (VGA)
 - $E \rightarrow E_T$ conversion
- Sampling:
 - 40 MHz, Flash-ADC (10 bit)
 - 1 ADC count = 250 MeV
 - Pedestal set at 32 ADC counts
- Bunch-crossing identification (BCID):
 - Finite Impulse Response (FIR) filter
 - Peak finder (linear/saturated)
 - Assign E_T to the “correct” bunch crossing
- E_T calibration:
 - Use a Look Up Table (LUT)
 - Pedestal subtraction, noise suppression
 - ADC (10 bit) \rightarrow GeV (8 bit) conversion

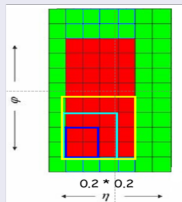
Region of Interest (RoI) finding

Cluster Processor

- Criteria for e/γ or τ/h :
 - EM or Had. cluster $> E_{\text{threshold}}$
 - Total E_T in EM(Had.) isolation ring \leq EM(Had.) isolation threshold
 - Local E_T maximum compared to neighbour windows
- Rols sent to Level-2



Jet/Energy-sum Processor



- Jet Candidate:
 - Coarser granularity 0.2×0.2 (Jet Element)
 - Digital summation EM + Had.
 - Sliding, overlapping windows (3 sizes)
- Missing & total E_T sums
- Rols sent to Level-2

L1Calo in USA15



Receivers & PreProcessors

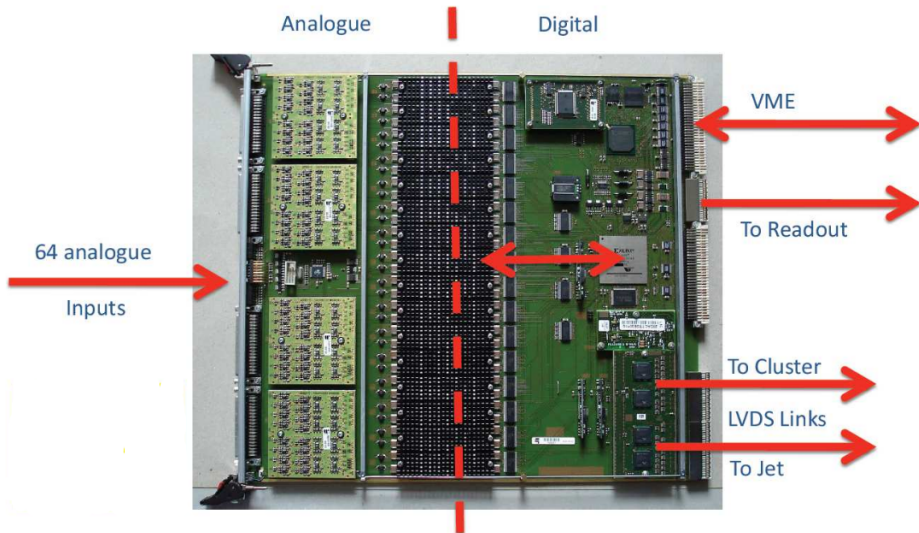


Processors



Readout Drivers

A PreProcessor module



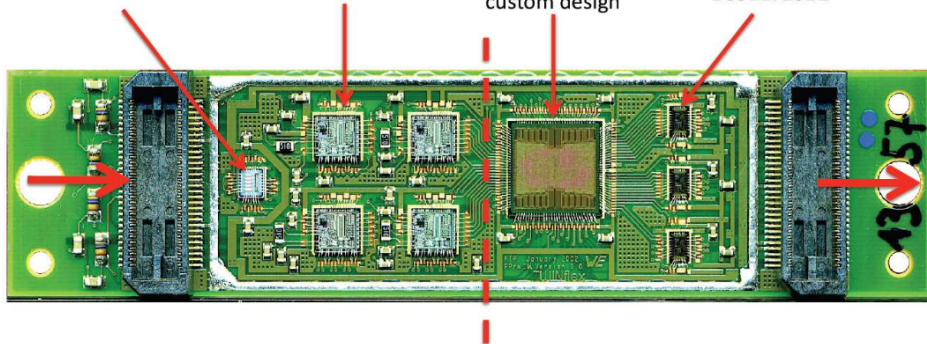
A PreProcessor Multi Chip Module (MCM)

PHOS4 precision 20
ps FADC strobe chip
(CERN / Heidelberg)

4 AD9042
12-bit
FADC chips

PPrASIC digital
processor, 0.6
 μm CMOS
Heidelberg
custom design

Low Voltage
Differential
Driver Chips
DS92LV1021



L1Calo Calibration

Timing calibration

- Everything has to be in time - system must look at same event
- Coarse timing (25 ns) - Find the correct bunch-crossing
- Fine timing (1 ns) - Sample the pulse at its peak

Internal calibration

- Set the same pedestal for all channels
- Bunch-crossing identification optimisation

Energy calibration

- Physics energies are in MeV not ADC counts
- Calibrating the ADC \rightarrow MeV conversion

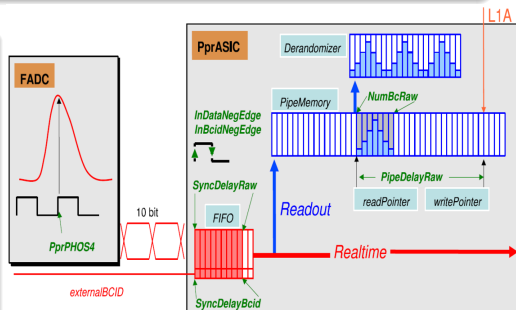
Timing calibration of L1Calo

Getting the timing right is critical

- The pp collisions take place at the interaction point
- Time of flight to calorimeters is η dependent
- Large variation in cable lengths from calorimeters to L1Calo
- Need to buffer early signals and process everything in time
- If we get the timing wrong we record the wrong event

Timing calibration

- For high physics acceptance everything must be in time
- Fine timing set by Phos4
 - Steps of 1 ns
- Coarse timing set in FIFO
 - Steps of 25 ns



PreProcessor coarse timing

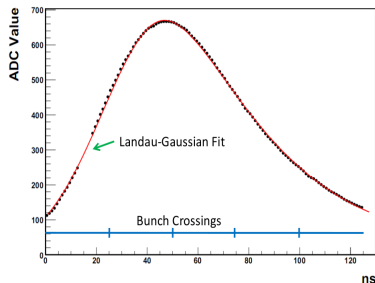
Input timing

- Use repetitive calorimeters pulser runs
- Line up analogue signals entering L1Calo PreProcessor
- Main source of variation is length of analogue cables coming from calorimeters with systematic variation along ϕ
- Establish timing in a calorimeter partition:
 - Barrel, End-Caps, Forward regions
 - Common offsets for all channels per partition
- Relative timing with a calorimeter partition:
 - Individual delays for all channels within a partition

Pulser runs setup to mimic physics timings

- Checking cross-partition timing with cosmics
- Priority for 1st beam is physics timing

PreProcessor fine timing - Phos4 scans



Timing channels to 1 ns

- Use repetitive calorimeter pulses
- Phos4 varies clock in steps of 1 ns
- Measure pulse for all 25 settings
- L1Calo records 5 bunch-crossings
- Measure the calorimeter pulse signal for 125 points
- Peak found by fitting offline

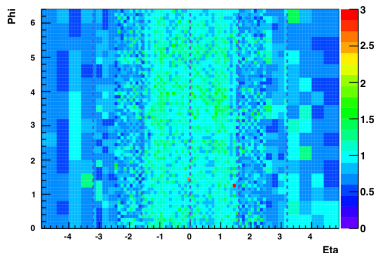
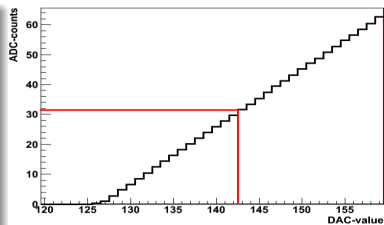
Saturated signals

- The maximum ADC counts of any channel is 1023 (10 bits)
- That's 255 GeV. We expect physics objects with $E_T > 255$ GeV
- Set the calorimeters' pulser energy to saturate L1Calo
- Phos4 runs used to tune our saturated peak finder

Setting and checking the pedestals

Setting the pedestal (DAC scans)

- Set the same pedestal for all channels
- Each channel has a different response
- DAC scan determines the relationship between ADC counts and DAC setting
- Each channel has different slope, offset



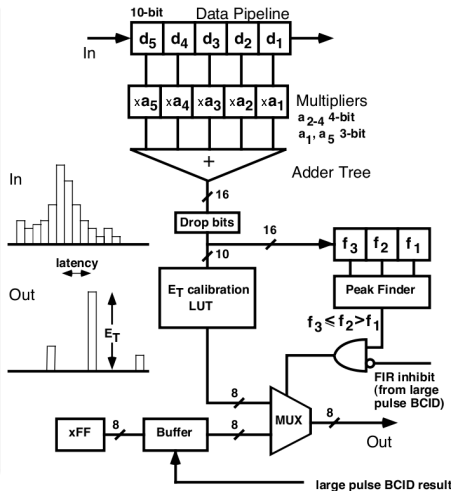
Checking the pedestal

- Determine pedestal value & width
- Shown is EM pedestal width
- Colour scale is ADC counts
- Width drops with η as $E_T = E \sin(\theta)$
- 2 Noisy channels in red

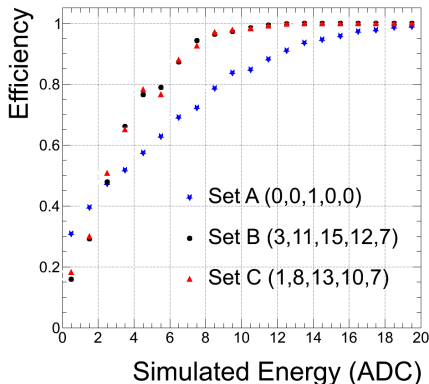
FIR filter coeffs - optimising bunch-crossing ID

Finite Impulse Response (FIR)

- Calorimeter signal pulses span many bunch-crossings
- The FIR filter coeffs improves:
 - BCID
 - Noise rejection
 - Energy measurement
- Use FIR filter coeffs matched to pulse shapes:
 - Coeffs \propto pulse height
 - Filter “sharpens” the pulses
- Each trigger tower can have its own FIR filter coeff setting



Effect of different sets of FIR filter coeffs



BCID Efficiency (MC study)

$$\epsilon = \frac{\text{\# pulses with correct peak}}{\text{All pulses}}$$

- Set A: just peak finder
 - performs worst
- Set B: FIR filter coeffs \forall channels
 - very complicated
- Set C: FIR filter coeffs set at region with largest noise ($\eta = 0$)
- Set B and Set C perform similarly

Early running strategy - Use Set C FIR filter coeffs

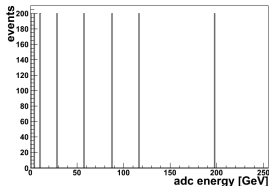
- Want to distinguish pulse from noise at low E_T
- Use just 3 FIR filter coeffs (EM, Had, Forward Calorimeter)
- Understand this first, then add complexity

Pulser calibration from calorimeters

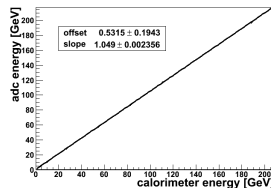
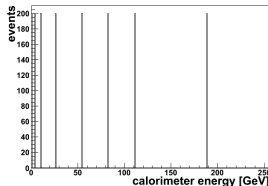
Calibrating the ADC \rightarrow MeV conversion

- Calorimeter calibration system provides pulser ramp runs
- Pulses provided in a sequence of different discrete amplitudes
- ~ 200 pulses per energy step. This is configurable
- Fit energy ramps and calculate calibration constants
- Aim for 1 ADC count = 250 MeV
- Tile and LAr calorimeter calibrations performed separately

trigger tower



calorimeter



Plans for 1st Beam

Physics calibration

- Coarse and fine timing from collisions a priority
- Offline analysis comparing reconstructed physics objects with L1Calo regions of interest
- Determine the electromagnetic scale
- **Understand the system**

After a bit of beam and a lot of understanding

- Optimisation:
 - Increase the number of FIR filters
 - Determining the hadronic scale
 - Dead material corrections
- Cross calibration:
 - Calibrate electron E_T to offline track E_T

Summary

Status of L1Calo

- By Sept. 2008 L1Calo was in a very good state
- As of Now, L1Calo is in an excellent state
- Near the limits of what can be done without beam

Calibration of L1Calo

- Timing from pulsers is known to 1 ns for all channels
- Energy calibration is advancing on many fronts
- Many sophisticated tools in place and working

Outlook

- We want beam!
- Very excited about the imminent collisions